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COMBAT SYSTEM SURVIVABILITY

Volume II—Overview of Combat System Survivability Model (CSSM), Sections 1 and 2

Science Applications, Inc.
8400 Westpark Drive
McLean, Virginia 22101

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Prepared for

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This report provides a description and documentation of the computerized combat systems survivability model (CSSM). The CSSM was designed and structured for use in the evaluation of the survivability of friendly combat systems and the vulnerability of hostile combat systems. The model focuses on damage achieved against targets in arrays which depict the elements of brigade, division, or larger size forces deployed on terrain in nominal or expected operating situations. The CSSM has the unique capability of determining both

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20. ABSTRACT (Continued)

the direct damage to and indirect effects on elements of the depicted tactical force. The model also has sufficient flexibility to support the evaluation of combat effectiveness following nuclear attacks, and to identify changes which could lead to improvements in combat mission capability during nuclear engagements.

The Combat System Survivability Model is used to perform the target or unit damage calculations as a function of target characteristics, threat levels, weapon effects, time after initial strike, and weapon application strategies. Based on resources expended, targets damaged/functions impaired and the assigned missions, assessments can be made on the capability of Combat Systems and forces to undertake military operations as a function of time.

Since numerous calculations and data manipulations are required to reflect variations in operational situations, weapons effects and attack strategies, the CSSM is used to expedite the determination of surviving assets and resources expended. The key elements of the CSSM consist of the following routines and processes:

- Acquired Target List Sub-Model
- Weapons Allocation Sub-Model
- Weapon Effects Sub-Model
- Direct Damage Calculation Sub-Model
- Indirect Damage Effects Sub-Model

The documentation part of the report is published in three volumes:

- Volume II - Overview of Combat Systems Survivability Model (CSSM),
- Volume III - Documentation of Sub-Models Used to Develop Input Data, and
- Volume IV - Documentation of Sub-Models for Target Damage Calculations.

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SECTION 1 - INTRODUCTION

1.1 GENERAL REMARKS

The purpose of this report is to present a description of the Combat System Survivability Model (CSSM). The development of this model was sponsored by the Vulnerability Directorate of the Defense Nuclear Agency (DNA).

The CSSM has been created to support a number of survivability/vulnerability studies conducted at SAI. Components of the CSSM were initially designed to evaluate the survivability of a U.S. brigade in tactical nuclear attacks. Further expansion of the Model was continued under two studies concerned with the survivability/vulnerability of deployed forces near the forward edge of the battle area (FEBA).

In addition to the above problems, the Model has been applied to other investigations associated with the use of US/NATO systems and forces in nuclear situations. These activities include an evaluation of nuclear cannon alternatives for DNA and Office, Deputy Chief of Staff for Military Operations (ODCSOPS), a determination of target damage requirements for DNA and SHAPE and an analysis of new technologies for theater nuclear operations for DNA and NATO.

1.2 DEVELOPMENT OF THE MODEL

In the early stages of development, the Model was designed to determine the level of direct damage achieved against deployed combat arms units subjected to a weapons laydown against acquired targets. Accordingly, the Model consisted of a target array, a simplified target acquisition routine, a scheme for assigning warheads to acquired targets, and a method for calculating damage to personnel and materiel in combat arms units near the nuclear burst point based upon selected damage criteria. A principal component of the initial CSSM is the Weapons Effects Sub-model which was undertaken to show the combined damage caused to targets by the nuclear and thermal radiation, blast and EMP as a function of distance from the burst, target characteristics, time after weapon laydown and physical environment. Thus, the initial model was used to summarize direct damage to units in a target array caused by nuclear attacks against acquired targets and other forces near the burst point.

The initial structure and detailed treatment of elements in the Model has continued to be refined and expanded in subsequent activities for DNA, ODCSOPS and HDL. These efforts have culminated in an improved weapon effects data base, mobile target acquisition methodology, targeting procedures and damage calculation.

The present weapon effects data base can reflect the implications of terrain shielding, tailored warheads, and damage criteria. The most recent DoD assessments for radiation and EMP effects on personnel and battlefield electronic equipment are incorporated into the data base.

The target acquisition methodology is now automated[a/] and considers the consequences of number and type of sensor assets, availability of target signatures, target time in position, frequency of observation, terrain masking, range to the target, visual and radar sensor performance, system response time and cover and concealment for the target. In addition, the methodology has been extended to treat the effects of SIGINT or ESM on target acquisition capability. Thus, the number and type of acquired targets can be specified as a function of distance from the FEBA in an operational context, when multiple sensors are employed to acquire multiple targets.

[a/] The automation of the mobile target acquisition routine was sponsored by Harry Diamond Laboratory (HDL) and completed in 1976.

The weapons allocation process has been expanded to permit the assignment of warheads to many targets and the logic has been extended to maximize bonus effects against units near the acquired target or suspected enemy position. The methodology has been refined to treat several targeting concepts including preclusion targeting, off-set aiming, troop safety, no fire zones and package/pulse firing doctrine.

The procedures for calculating direct damage to units near the burst point was modified in the recent combat systems survivability/vulnerability studies to permit the treatment of targets as either point or area. In addition, the methodology has been revised to include the cumulative effects of radiation over time from subsequent weapon laydowns. The formats for summarizing target damage have been expanded to show numbers of personnel and types of materiel within a unit exposed to various levels of weapon effects and damage can be indicated for units as a function of various levels of damage criteria or unit incapacitation. Average or expected levels of damage can be calculated for all types of combat arms units as a function of either distance from the burst point or total weapons laydown.

The damage calculation methodology has been extended to consider the impact of indirect effects on capability of surviving units to carry out combat missions. These indirect effects are caused by damage to supporting units which produce an interruption in the flow of information, personnel or materiel needed by the surviving combat arms units. Thus, the damage caused by both direct and indirect effects in a nuclear attack against a deployed force can be reflected in the Model results.

1.3 COMPONENTS OF MODEL

The design and structure of the CSSM for use in the evaluation of combat system survivability/vulnerability focuses on calculating damage achieved against targets deployed in the terrain under nominal or expected operating situations. Accordingly, emphasis is on the determination of direct and indirect damage sustained against critical elements of the brigade or division forces. In addition, sufficient flexibility is maintained so changes which could lead to improvements in the capability to undertake combat missions during nuclear engagements can be identified by the exercise of the Model.

The Combat System Survivability Model is used to perform damage calculations as a function of target characteristics, threat levels, weapon effects, time after initial strike, and allocation strategies. Based on resources expended, targets damaged/functions impaired and the assigned missions, assessments can be made on the capability of combat systems and forces to undertake military operations as a function of time.

Since numerous calculations and data manipulations are required to reflect variations in operational situations, weapons effects and attack strategies, the CSSM is used to expedite the determination of surviving assets and resources expended. The key elements of the CSSM are portrayed in Table 1-1 and consist of the following routines and processes:

- Acquired Target List Sub-model
- Weapons Allocation Sub-model

- Weapon Effects Sub-model
- Direct Damage Calculation Sub-model
- Indirect Damage Effects Sub-model.

Table 1-1. Key elements of combat system survivability model.

SUBMODELS	FEATURES OF MODEL	PRIMARY OUTPUT
ACQUIRED TARGET LIST	• TARGET LIST BY RANGE • TIME PERIOD OF INTEREST • PROBABILITY OF ACQUISITION	• LIST OF POTENTIAL TARGETS
WEAPONS ALLOCATION	• TARGET VALUE/VULNERABILITY • DAMAGE OBJECTIVES • TARGET DYNAMICS • WEAPON CHARACTERISTICS • TARGET LOCATION ERRORS • TARGETING CONSTRAINTS	• TARGET SELECTION • WEAPON AIM POINTS
WEAPON EFFECTS	• TARGET EXPOSURE • ENVIRONMENT • TARGET VULNERABILITY • TARGET RESPONSE • DAMAGE CRITERIA (EMP BLAST, THERMAL & NUCLEAR RADIATION)	• PROBABILITY OF INCAPACITATION OR DAMAGE AS FUNCTION OF WEAPON CHARACTERISTICS AND RANGE FROM BURST POINT
DIRECT DAMAGE CALCULATION	• WEAPON AIM POINTS, CEPs, YIELDS AND HOB • TARGET CHARACTERISTICS/DEPLOYMENTS • DAMAGE CRITERIA • RULES FOR ASSESSING DAMAGE	• DAMAGE TO ATTACKED PERSONNEL AND MATERIEL • DAMAGE TO NEARBY TARGETS (BONUS EFFECTS)
INDIRECT DAMAGE CALCULATION	• PROBABILITY OF DIRECT DAMAGE TO SUPPORTING UNITS • UTILIZATION LEVEL FOR EACH UNIT (NODE) • STORAGE TIME AT SURVIVING UNITS • RECOVERY AND REPLACEMENT TIME FOR DAMAGED NODES	• FRACTION OF IMPAIRED UNITS DUE TO INTERRUPTIONS IN FLOW OF REQUIRED SUPPORT

A routine is contained in the CSSM for surveying detailed damage to the combat forces in terms of target type, combat units and functional areas affected by the nuclear attack as a function of time and nuclear resources, as well as a listing and description of the targets used in the array. The model results are presented in terms of an overview of the damage, including the fraction of the combat units incapacitated to specified levels by each type of weapon effect (blast, thermal, nuclear radiation and EMP) and the combat functional areas destroyed per combat phase. The model can be exercised to permit an examination of the sensitivity of study results to variations in operation conditions, environmental situations, threat characteristics and weapon effects. The direct damage to units serves as principal input data for the assessment of indirect nuclear effects.

1.4 TYPES OF NUCLEAR DAMAGE

Before introducing some of the key aspects of the routines and sub-models involved in the CSSM, a brief discussion of the types of damage caused by weapon laydowns against a target array is useful. The types of nuclear damage provide a background for considering the dimensions of the model designed to determine the survivability/vulnerability of mobile forces near the FEBA.

Figure 1-1 presents an illustration of the types of effects that can be produced by a nuclear attack. These effects are considered to cause either direct or indirect effects. The direct effects produce losses of personnel/materiel in combat arms units near the burst point. The direct nuclear effects produce damage which may result in unit incapacitation (unavailability of the unit for military actions) or unit degradation (due to some losses in personnel or materiel). The indirect nuclear effects cause unit impairment due to the interruption of support to surviving units.

The direct effects from nuclear bursts are postulated to incapacitate combat units when a certain fraction of the personnel or materiel within the unit is unable to carry out designated tasks or functions. The number of units incapacitated by a prescribed weapons laydown depends upon the unit incapacitation criteria, the distance between the burst point and the nearby units, the shielding available at the units and the environmental conditions. Damage to personnel/principal equipment is treated in terms of the blast, nuclear radiation, thermal radiation, and EMP levels experienced by the elements of the combat arms units. In short, incapacitated units are considered to be unable to participate in the combat mission assigned to the force.

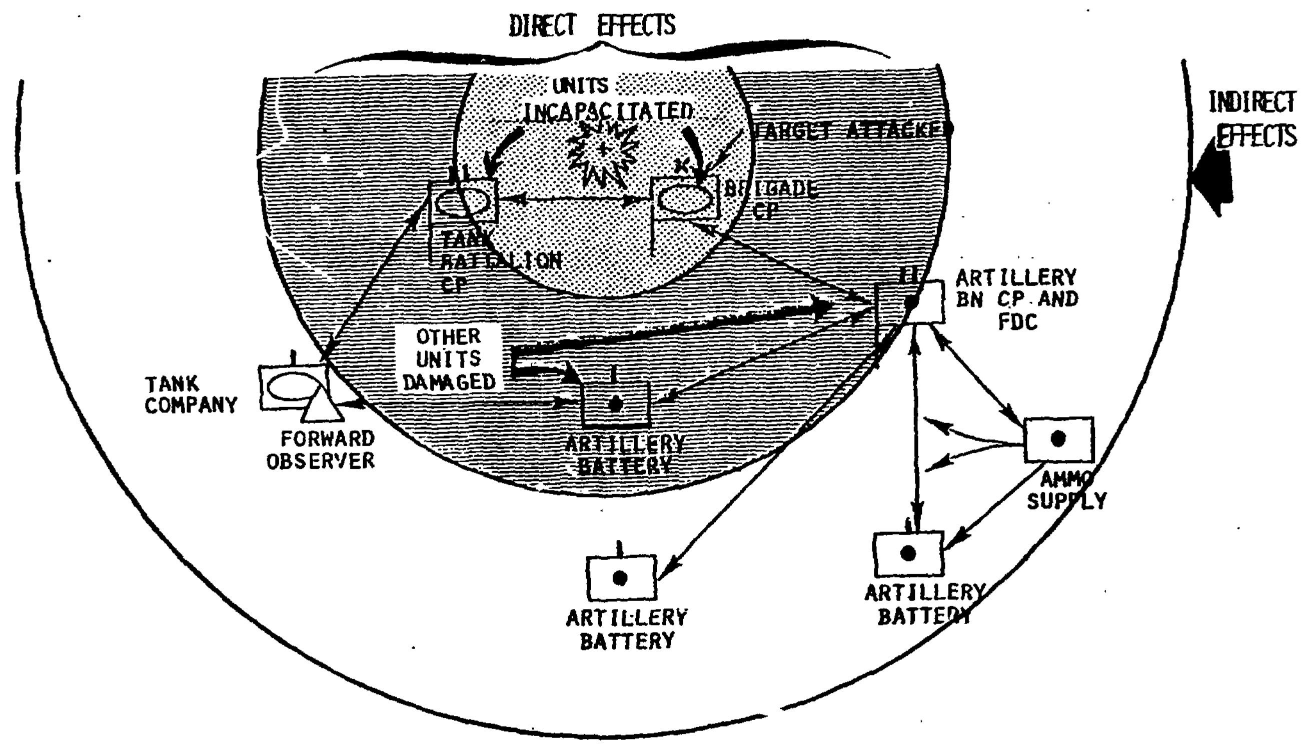

Figure 1-1. Example of types of nuclear effects on combat units.

The indirect effects from nuclear bursts are expected to cause temporary reductions in the combat capability of surviving units. Impairment in capability is caused by an interruption in the flow of personnel, combat materiel or information needed by surviving units before tasks or missions can be completed.

Degradations can occur in partially damaged units from the decrease in combat capability caused by the loss of materiel or personnel in the unit. This reduction in capability can evolve from direct damage to the unit which must be compensated by reassigning personnel/materiel or by repairing damage to elements using assets within the unit.

The level of damage achieved by direct effects is closely related to two factors. These are the number of warheads delivered on selected targets and the damage sustained against targets near the burst. Based upon the expected nuclear warhead yields, delivery system accuracies, and target location errors analyses reveal that an engaged platoon/battery size combat unit becomes a dead target. Even considerations of troop safety and limits on maximum permissible yields fail to offer survivability to most of the targets selected for nuclear attack near the FEBA. Accordingly, the major thrust of the direct effects calculations is directed toward a determination of damage achieved against other targets near the nuclear burst point (bonus effects).

The bonus effects depend upon the spacing between combat units and the posture of the personnel within the targets. The number of nuclear warheads delivered on targets is a direct function of the capability to acquire appropriate targets, the amount of firing time and the launch/sortie rate. Target spacing, exposure of personnel in each unit, and number of delivered warheads depend on the phase of combat.

The level of damage achieved against the combat forces due to the indirect effects depends to a large extent upon the actual type of targets affected by the nuclear weapons laydown. Since the actual targets acquired and engaged in the weapons laydown is a random or probabalistic process, significant variations can occur in the total damage sustained against the combat forces. Accordingly, analyses of the indirect effects should be structured to show bounds on the level of damage expected by these temporary reductions in combat capability.

An extensive effort has been underway to modify the direct damage analysis to reflect the capability of partially damaged units to participate in combat missions as a function of time after a nuclear attack. Attention has been devoted toward an appraisal of the capability of partially damaged units to transfer or reassign personnel for other actual mission tasks or repair damages in the principal equipment. A key element in this analysis of recovered unit capability is the level of damage sustained by the individual units. Also, the unit damage threshold must be specified or estimated for which sufficient damage has been inflicted to cause a unit to be ineffective for the duration of the assigned mission. While the current damage procedure will permit the determination of level of damage to each combat arms unit, the assessments of direct damage by the model do not reflect the degradation in combat capability due to partially damaged units. In support of the Target Damage Requirements Study, research is underway to finalize the procedures and methods for treating the effects of losses in personnel or combat materiel on unit capability over time. Accordingly, the description of the partially damaged unit analysis will be reported in a separate document upon completion of the analysis.

1.5 ORGANIZATION OF THE REPORT

The description of the CSSM and user's guide is contained in three volumes. The first volume (II) is unclassified and presents an overview of the salient features and components in the combat system survivability model. The input data is presented in the second volume (III) and has an overall classification of Secret. The final volume (IV) contains target damage calculations for direct and indirect nuclear effects.

The next section (2) of this volume describes the components of the CSSM. The processes and activities associated with each of the sub-models or routines are outlined and the interface between the components of the Model are noted. The types of data input, calculator routines and output or results produced by the Model are highlighted in Section 2.

The input data used by the model to determine the weapon aimpoints and the target or unit exposure to the nuclear environments associated with selected weapon laydowns or attacks is defined in Sections 3, 4, and 5 (Volume III). Section 3 describes the characteristics of the target acquisition procedures and methodology for determining the acquired target list in a given target array. The weapons allocation process and options for targeting are outlined in Section 4. The weapon effects data base and procedures for determining level of target exposure are presented in Section 5 for nuclear and thermal radiation, blast and EMP as a function of distance from the burst point, warhead yield and target posture.

The procedures for calculating target damage are presented in Sections 6, 7, and 8 of Volume IV. Section 6 shows the procedures of user's guide for determining direct damage to target elements (personnel or materiel) as well as incapacitated units based upon specified damage criteria. A description of the methodology and operations involved in the calculation of indirect damage is contained in Section 7. The activities and routines used to calculate <u>both</u> direct and indirect effects from a weapons laydown against a target array are summarized in the final section (8).

SECTION 2 - STRUCTURE OF THE MODEL

2.1 GENERAL REMARKS

This section presents a description of the organization and structure of Combat System Survivability Model. The features and characteristics of the routines and procedures involved in each of the sub-models are outlined. In addition, a brief discussion is included on the types of input and results generated by each sub-model.

The presentation in this section is divided into the two categories of direct and indirect damage effects. This section is intended to serve as a background and perspective for considering the detailed characteristics of each sub-model presented in subsequent sections of the report (Volume II and Volume III).

The Combat System Survivability Model is designed to indicate the damage to combat elements, units and functional areas from direct and indirect effects associated with plausible nuclear attacks. The results of various levels and types of nuclear attacks are converted into an identification of surviving assets, a delineation of incapacitated units, and an assessment of degradations in capability to perform combat missions/functions. These conversions or results are based upon the given target array, nuclear weapon characteristics, acquired target list, weapon allocation strategy, and damage criteria.

Targeting strategies and options can be tailored to satisfy delivery system constraints, nuclear firing doctrine, and desired damage objectives. Values and assumptions on troop safety considerations, permissible spread in firing times, allowable distances between nearby burst points (firing windows) and available nuclear assets can be incorporated into the targeting concepts.

The direct effects from nuclear bursts are measured in terms of the fraction of personnel or materiel within the unit which is considered incapacitated or damaged according to specific criteria. The number of incapacitated units from a prescribed weapons laydown depends upon the unit incapacitation criteria, the distance from the burst point, the shielding available at the target, and the environmental conditions. Damage to personnel/principal equipment is treated in terms of the blast, nuclear radiation, thermal radiation, and EMP levels experienced by the elements of the combat units. In short, incapacitated units are considered to be unable to participate in the combat mission assigned to the deployed force.

The indirect effects from nuclear bursts are expected to cause temporary degradations in the combat capability of surviving units. Degradations in capability are caused by an interruption in the flow of personnel, combat materiel or information needed by surviving units before tasks or missions can be completed. Accordingly, impairment is postulated to evolve from direct damage to units which support a surviving unit.

2.2 DIRECT EFFECTS CONSIDERATIONS

2.2.1 Key Elements and Procedures

This section presents an overview of the various elements of the Direct Effects Sub-model. Thus, this section provides a framework for describing the required input data, major assumptions, and critical factors involved in the engagement analysis and direct target damage calculations. Also, a description of the procedures and the exercises performed by the model are outlined to provide an indication of the data requirements and type of results that can be produced in the assessment of combat system survivability/vulnerability.

The key elements or sub-models associated with the Direct Damage Effects consist of the following:

- Acquired Target List Sub-model (ATLM)
- Weapon Allocation Sub-model (ALGM)
- Weapon Effects Sub-model (WEM)
- Direct Damage Calculation Sub-model (DDCM).

Each of the sub-models can be exercised as separate operations. Thus the CSSM has the flexibility to be operated as only a target acquisition model for mobile targets or as a means for printing weapon effects environments or as a technique for assigning weapons to targets.

The Direct Damage Effects portion of the CSSM has a routine for portraying detailed damage to the combat force in terms of target type, combat units and functional areas affected by the nuclear attack as a function of time and expended nuclear resources. Also, a listing and description of the targets used in the analysis are included. The results are presented in terms of an overview of the damage to the combat force, including the fraction of units in each combat functional area damaged to specified levels by each type of warhead effect (blast, thermal and nuclear radiation and EMP) and the combat arms units* destroyed per weapon laydown. Procedures and routines are provided to permit examination of the sensitivity of results to variations in operational situations, environmental conditions, delivery system characteristics and warhead effects.

The military scenario or operational situation lays the framework for the survivability/vulnerability assessment. The scenarios are postulated to reflect a variety of defense and attack formations involved in the various phases of combat. Thus, the combat variations can influence the assessments in the following ways:

- Affect the disposition and posture of the force
- Modify the assessment routine by changing the importance of functional areas

*Combat arms units are considered to be resolved down to platoon/battery size forces deployed in the terrain and include artillery, maneuver, antitank, air defense, target acquisition and command and control. Other combat support and service support units affected by the nuclear bursts can be tabulated as desired.

- Alter the attacker goals or objectives
- Constrain the firing time and weapons available to attack the combat formations.

The exercises involved in the assessment are designed to account for changes in target development capability, nuclear assets, nuclear delivery means, and nuclear employment policy. Based on resources expended, targets damaged/functions impaired, and the assigned missions, assessments can be made of the capability to undertake combat operations as a function of time.

2.2.2 Features of Direct Effects Calculations

The above noted sub-models have been developed to handle numerous calculations and data manipulations required to reflect variations in operational situations, weapons effects and attack strategies. Use of these sub-models (ATLM, ALGM, WEM, and DDCM) with appropriate description of the target characteristics and the damage summary routines comprises the elements of the Direct Damage Effects Assessment.

Table 2-1 shows the key components which are included in the Direct Damage Effects Assessment. Routines and logic are available for performing calculations dealing with weapon effects, target vulnerability, nuclear weapons allocation and target damage.

In developing the Direct Damage Effects Assessment, two goals have been kept in mind. First, the model components must be sensitive to those factors and parameters which could possibly influence combat force survivability/vulnerability. This is necessary to permit a sensitivity analysis that reveals critical vulnerabilities in the force and explores the value of proposed measures designed to enhance survivability. Second, the model components must be generalized to be applicable to other DoD sponsored research projects.

The Acquired Target List Sub-model (ATLM) operates on the available list of targets to determine the number of each type of acquired target.

Table 2-1. Key components of direct damage effects assessment.

Direct Effects Sub-model	Driving Factors/Parameters	Model Applications
Acquired Target List Sub-model	Target list by range Time period of interest Probability of Acquisition	List of potential targets
Weapons Allocation Sub-model	Target value/vulnerability Damage objectives Target dynamics Weapon characteristics Target location errors Targeting constraints	Target selection Weapon aim points Weapon yields
Weapon Effects Sub-model	Target exposure Environment Target vulnerability Target response Damage criteria (EMP, blast, thermal, nuclear rad)	Probability of incapacitation/damage as function of: Weapon characteristics Distance from burst point Damage criteria
Direct Damage Calculation Sub-model	Weapon aim points, CEPs, yields, and HOB Target characteristics/deployments Damage criteria Rules for assessing damage Format for output	Damage to attacked personnel/materiel Damage to combat units Damage to types of targets Bonus effects

The number of targets attacked by each group of target acquisition means is determined by the probability of acquisition and the number of each type of target in each range band. A Monte Carlo technique is used to select the actual types and location of targets as a means to simulate the operational situation. In this process, targets with similar characteristics and probabilities of acquisition are grouped and processed together to determine which targets are acquired. A sufficient number of runs is undertaken to provide a reasonable estimate of the expected targets by type and characteristics (similar signatures, size and composition).

The target acquisition model is automated to reflect consequences of variations in the operational factors, terrain masking, response time, environment, target characteristics, sensor assets, and sensor performance on capability to acquire mobile targets as a function of time. In addition, the model includes a subroutine for reflecting the capability to acquire targets using SIGINT means.

Weapons are allocated against the acquired list using the Weapons Allocation Model (ALGM) which can account for desired attack strategies and constraints on available weapons. The weapons are allocated on the basis of target value and capability to damage each target using a modified Lagrange Multiplier technique. Target value depends upon target importance or priority, capability to acquire targets, number of targets, and capability to damage each type of target. Yields are based upon the strategy of either matching target vulnerability with the appropriate yield or achieving increased target damage against adjacent targets (bonus effects).

The Weapon Allocation Sub-model considers target location error (TLE) in determining desired aimpoint for each nuclear weapon. Consideration is given to location of each type of weapon and range to the target in determining delivery system accuracy (CEP) and TLE. Desired damage levels are used to ensure that sufficient effects are achieved to cause combat incapacitation on various types of targets without expending too few or too many weapons.

The allocation procedures can either reflect "actual troop safety" targeting based upon warhead yield and CEP or utilize a simplified scheme based on no fire zones and allowable yields in range bands near the FEBA. Preclusion or off-set procedures can be introduced to avoid prescribed levels of damage to urban centers.

Weapons can be allocated against on-road targets (moving) based upon postulated errors in movement rates and angular errors. For targets on the move, the Weapons Allocation Sub-model uses a computational method for assigning up to two warheads on a single target. Targets that have finite times in position before moving to subsequent positions are treated by considering the fraction of targets by type that can be acquired and engaged during target time in position. No accounting is made for weapons expended against targets that move before warhead arrival.

The Weapons Effects Sub-model (WEM) shows the probability of damage to targets or units as a function of distance from the burst and time after weapon laydown. The fraction of personnel exposed to blast, thermal radiation and nuclear radiation are calculated for prescribed target postures and damage criteria. Incapacitation to personnel is calculated in a unit by the number of personnel in the open (prone or standing), in foxholes, in weapon emplacements and in combat vehicles. The amount of principal equipment exposed to blast and EMP effects is calculated according to specified damage criteria and protection factors. Nuclear blast effects to principal equipment can be determined for light, moderate (M-1 and M-2 levels) and severe levels of damage. Electrical equipment vulnerability to EMP effects must be specified to determine the fraction of systems exposed to damage at a given distance from the burst point. The current model treats only the vertical component of EMP for combat materiel.

The Direct Damage Calculation Sub-model uses the designated aim point and the warhead yield defined by the Weapons Allocation Sub-model (ALGM) to specify the damage to all targets near the burst point of the nuclear warhead. Thus, the direct damage calculations is based upon the data in the Weapon Effects Sub-model (WEM) to determine damage to targets near the burst point of the nuclear warhead. The burst point is different from the aim point due to delivery system errors associated with the nuclear delivery system.

2.3 INDIRECT EFFECTS CONSIDERATIONS

2.3.1 Key Elements and Procedures

The portion of the Combat System Survivability Model concerned with the impairment in capability due to indirect effects is briefly described in this section. Indirect effects evolve from interruptions in the flow of personnel, materiel, or information to surviving units as a consequence of direct damage to other units.

In the design of the indirect effects portion of the CSSM, emphasis centers upon the probability of incapacitation of the supporting units or nodes by direct damage, the need for external support, and the time for recovery or replacement of the damaged support unit. The probability of damage to supporting nodes is determined from weapon laydowns against acquired or suspected targets in the combat area. Results from various levels of nuclear attacks are portrayed in terms of the fraction of surviving units unable to perform designated tasks or functions during the combat mission lifetime. Impairment in capability due to indirect effects presented as a function of time after the weapons laydown.

The principal building blocks for the Indirect Damage Assessment are:

- Task Decision Structure
- External Unit Damage Procedures

- Unit Recovery and Replacement Operation
- Indirect Damage Calculation Process.

The assessment of the indirect effects and the impact on the combat effectiveness of tactical units can be accomplished through the use of an analytical procedure described as a decision or fault tree structure. In this procedure, the combinations of ways that an interruption can occur in the flow of external support needed by surviving elements to undertake designated functions or tasks are constructed. A fault (undesired event) can occur if support is required by a surviving unit and a breakdown in the flow of support occurs. This breakdown in support can be caused by the loss of a single unit in a direct transfer path option or the loss of all the units in a multiple transfer path option. Paths are developed for each combat function or task to indicate how support is transfered to the surviving units. Then, the indirect effects on surviving units are measured in terms of the degree of impairment in capability to perform a task over time.

2.3.2 Features of Indirect Effects Calculations

In order to determine the indirect damage from nuclear attacks, a number of support flow charts (decision trees) and calculations must be developed for each function or task of interest. Data calculations are undertaken in the above mentioned procedures and routines to ascertain the level of direct damage sustained to supporting units or nodes, the capability of nodes to recover or be replaced over time, and the need for external support by the surviving units.

Table 2-2 displays the input data required for the indirect nuclear effects calculations. Input data are described in terms of the key parameters and factors influencing the level of indirect effects. The unique characteristics of the direct damage effects portion of the CSSM provide a suitable and appropriate means to determine the probability of damage to nodes in the decision or

Table 2-2. Input data for indirect damage effects.

Key Parameters	Descriptors	Factors Influencing Input Value
Probability of Damage	Direct nuclear damage to nodes in the task fault tree	• Direct damage criteria • Intensity of attack in combat area • Phase of combat
Utilization Level	Frequency of use of nodes in task fault tree	• Type of task • Dependence of support by node • Means available to provide support
Storage Time	Need for external support by the surviving combat units	• Demand rate for external support • Nominal support rate • Combat situation
Recovery/ Replacement Time	Availability of nodes to meet demand levels	• Type of node • Alternate means to provide support • Recuperation rate at node

fault tree for each task. The input data for the other parameters are developed from considerations of the concepts of operation, the nominal scheme for the flow of support, and military estimates of the times and need for support.

The development of the Decision or Fault Tree involves the formulation of a chain of supporting events or activities that are both external to the surviving units and are needed before designated tasks or functions can be completed. A fault can occur from situations or combinations of actions caused by direct nuclear damage to supporting units that lead to an interruption in the flow of personnel, materiel or information to surviving units assigned to carry out specific combat functions like deliver fire or provide protection from air strikes.

External damage to supporting units evolves from weapon laydowns in the combat area that incapacitate units serving as a node or conduit for surviving units. The probability of incapacitation for supporting units is extracted from the Direct Damage Calculation Sub-model based upon considerations of unit incapacitation criteria and type of unit.

The Indirect Effects Calculation Sub-model uses the probability of damage to supporting units, the times for supporting units to recuperate or be replaced and the need for external support to determine the fraction of units unable to perform designated tasks or missions. The need for external support depends upon the storage capacity at the surviving unit and the utilization rate of the supporting units or nodes.

2.4 SEQUENCE OF MODEL OPERATIONS

2.4.1 Selection of Input Data

The general sequence of activities involved in the CSSM is illustrated in Figure 2-1. The operations begin with a target array that can be generated by the user or selected from approved military scenarios. Vulnerability programs using the CSSM include an enemy division target array on the offensive, in the approach march, preparation, breakthrough, assault and shallow penetration phases of combat. Also, target arrays have been developed for US brigades and divisions in position defenses against the enemy in the above mentioned situations along with a counterattack situation.

In order to determine direct and indirect damage to combat arms units in the target array, the characteristics and location of the units must be specified. The location of the units in the terrain permits the evaluation of combat system survivability/vulnerability in an operational context. In addition, the damage calculations can be made against units according to the ways in which the elements of the force will be acquired and engaged. Unit characteristics of concern to the CSSM include the target type, physical dimensions, composition, posture, activity, time in position and cover/concealment. In short, a detailed target array containing high resolution units (equivalent to platoon/battery size) in postulated military situations is used to determine the capability to acquire combat arms units, assign warheads and calculate damage to acquired and nearby targets of interest.

The number and type of sensors must be indicated for use in determining the acquired list of targets in the presented target array. Also, the concept for using each of the sensor types must be selected including the frequency of utilization, platform flight profile, degree of visibility, target activity and time period of interest. Target location errors are specified according to principle sensor capability for each type of target or weighted according to the fraction of targets acquired by each sensor means.

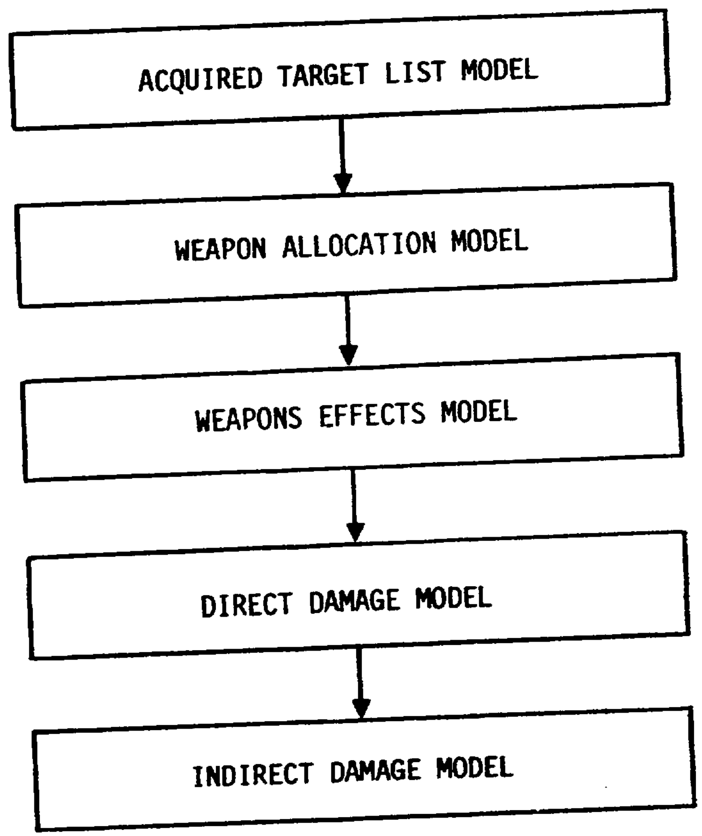

Figure 2-1. Sequence of operations in CSSM.

The list of available weapons for use against the target array must be designated. Delivery system characteristics including yield, effective range, CEP and response time are provided as input to the Weapons Allocation Sub-model. Also, estimates for uncertainties in target movement rates and direction can be input for attacks against on-road targets.

In order to assign weapons to selected targets or suspected enemy positions, attacker objectives can be specified to ensure desired target damage. Targeting constraints can be input to meet required troop safety and collateral damage guidelines. In addition, rules can be implemented to ensure that the weapon laydowns meet constraints on uses for particular weapon types, no fire zones, warhead yield limitations, in designated range bands, firing windows (time and distance between burst points) and selection of large yields to increase bonus effects. Factors can be included to reflect the consequences of delivery system reliability or attrition on numbers of warheads assigned to targets.

To determine the fraction of units exposed to various weapon effects in an attack, values for target incapacitation must be input to the Weapon Effects Sub-model. Thus, the level at which personnel are expected to become combat incapacitated from exposure to nuclear and thermal radiation, and to blast overpressure must be indicated. Similarly the levels for light, moderate and severe damage from nuclear effects must be noted for equipment of interest. The vulnerability of electrical components to EMP effects can be indicated in terms of threshold levels of exposure for various categories of equipment hardening. Also, the physical environment must be specified in terms of time of year, degree of visibility, amount of vegetation and presence of inclement weather. The WEM can also include the significance of terrain effects on target damage. Of course, terrain elevations at about 500 meter intervals must be included in the description of the the target array before the consequences of terrain masking or reflection can be incorporated into the damage assessment.

2.4.2 Computational Exercises

Based upon the procedures and logic developed for the CSSM, together with representative input data, a number of operations can be undertaken with the model. Some examples of computations that can be conducted by the CSSM are as follows:

- Generation of an acquired target list over time by target type, range band, distance from FEBA and/or target value from the available targets in division or brigade array.
- Selection of weapon aim points for each acquired target as a function of targeting constraints and attack time.
- Assignment of warheads to selected targets by yield and weapon type according to target location, targeting constraints and damage objectives.
- Calculation of direct target damage from each type of weapon effects as a function of distance from a burst point, type and yield of warhead, target characteristics and physical environment.
- Determination of combat arms units damaged by direct nuclear effects as a function of type of unit, target damage criteria, unit incapacitation criteria, time after attack, target acquisition capability and number/type of weapons involved in the nuclear attack.
- Determination of bonus effects achieved with weapons laydowns against designated targets or suspected positions.
- Determination of average or expected level of direct damage to combat arms units by type of unit and intensity of nuclear weapons laydown or attack.

- Determination of impairment to combat arms units by indirect nuclear effects as a function of intensity of nuclear weapons laydown, target and unit incapacitation criteria, target acquisition capability and type of unit mission or task.

2.4.3 Computational Results and Summaries

The design of the Model has been structured to provide considerable flexibility to the user in specifying formats for results, amount of detailed information and data summaries. In addition, individual sub-models can be operated without operating the complete model. For example, the Indirect Damage Effects Sub-model can be exercised by using average or expected levels of damage to supporting nodes rather than using direct damage calculations obtained from a particular weapons laydown against the target array.

Some examples of results that can be produced by the model are listed below:

- Attacker resources expended as a function of time.
- Summary of targets and combat arms units damaged by direct effects as a function of time and location of units.
- Fraction of combat functional areas damaged by direct effects as a function of incapacitation criteria.
- Fraction of individual targets or units receiving specified levels of exposure to nuclear weapon effects.
- Number of combat arms units damaged per expended warhead in a given nuclear attack situation.
- Fraction of combat functional area damaged by indirect effects as a function of time after weapons laydown.

Identification of critical choke points or key vulnerabilities in the target array due to indirect effects caused by losses in support to surviving combat arms units.

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